1.3 RAPID EXIT TAXIWAYS (RETS)

General

1.3.1 A rapid exit taxiway is a taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than those achieved on other exit taxiways, thereby minimizing runway occupancy time.

1.3.2 A decision to design and construct a rapid exit taxiway is based upon analyses of existing and contemplated traffic. The main purpose of these taxiways is to minimize aircraft runway occupancy and thus increase aerodrome capacity. When the design peak hour traffic density is approximately less than 25 operations (landings and take-offs), the right angle exit taxiway may suffice. The construction of this right angle exit taxiway is less expensive, and when properly located along the runway, achieves an efficient flow of traffic.

1.3.3 The establishment of a single worldwide standard for the design of rapid exit taxiways has many obvious advantages. Pilots become familiar with the configuration and can expect the same results when landing at any aerodrome with these facilities. Accordingly, design parameters have been established in Annex 14, Volume I for a grouping of exit taxiways associated with a runway whose code number is 1 or 2 and another grouping for code number 3 or 4. Since the introduction of rapid exit taxiways, additional field tests and studies have been conducted to determine taxiway utilization, exit taxiway location and design, and runway occupancy time. Evaluation of such material has led to the development of exit taxiway location and design criteria based on specified aircraft populations moving at relatively high speeds.

1.3.4 There is some difference of opinion with respect to the speed at which pilots negotiate rapid exit taxiways. While it has been inferred from some studies that these taxiways are normally used at a speed not higher than 46 km/h (25 kt) and even in some cases at lower speeds when poor braking action or strong cross-winds are encountered, measurements at other aerodromes have shown that they are being used at speeds of over 92 km/h (49 kt) under dry conditions. For safety reasons 93 km/h (50 kt) has been taken as the reference for determining curve radii and adjacent straight portions for rapid exit taxiways where the code number is 3 or 4. For computing the optimum exit locations along the runway, however, the planner will choose a lower speed. In any case, the optimum utilization of rapid exits requires pilot cooperation.

Instruction on the design of, and benefits to be obtained from use of, these taxiways may increase their use.

Location and number of exit taxiways

Planning criteria

1.3.5 The following basic planning criteria should be considered when planning rapid exit taxiways to ensure that, wherever possible, standard design methods and configurations are used:

a) For runways exclusively intended for landings, a rapid exit taxiway should be provided only if dictated by the need for reduced runway occupancy times consistent with minimum inter-arrival spacings;

b) For runways where alternating landings and departures are conducted, time separation between the landing aircraft and the following departing aircraft is the main factor limiting runway capacity;

c) As different types of aircraft require different locations for rapid exit taxiways, the expected aircraft fleet mix will be an essential criterion;

d) The threshold speed, braking ability and operational turn-off speed (V_{ex}) of the aircraft will determine the location of the exits.

1.3.6 The location of exit taxiways in relation to aircraft operational characteristics is determined by the deceleration rate of the aircraft after crossing the threshold. To determine the distance from the threshold, the following basic conditions should be taken into account:

a) threshold speed; and

b) initial exit speed or turn-off speed at the point of tangency of the central (exit) curve (point A, Figures 1-13 and 1-14).

Design, location and number of rapid exit taxiways

1.3.7 Determining the optimum location and required number of rapid exit taxiways to suit a particular group of aeroplanes is recognized as a comparatively complex task owing to the many criteria involved. Although most of the operational parameters are specific to the type of aircraft with respect to the landing manoeuvre and subsequent braked deceleration, there are some criteria which are reasonably independent of the type of aircraft.

1.3.8 Accordingly, a methodology, known as the Three Segment Method, was developed which permits the determination of the typical segmental distance requirements from the landing threshold to the turn-off point based on the operating practices of individual aircraft and the effect of the specific parameters involved. The methodology is based on analytical considerations supplemented by empirical assumptions, as described below.

1.3.9 For the purpose of exit taxiway design, the aircraft are assumed to cross the threshold at an average of 1.3 times the stall speed in the landing configuration at maximum certificated landing mass with an average gross landing mass of about 85 per cent of the maximum. Further, aircraft can be grouped on the basis of their threshold speed at sea level as follows:

Group A — less than 169 km/h (91 kt)

Group B — between 169 km/h (91 kt) and 222 km/h (120 kt)

Group C — between 224 km/h (121 kt) and 259 km/h (140 kt)

Group D — between 261 km/h (141 kt) and 306 km/h (165 kt), although the maximum threshold crossing speed of aircraft currently in production is 282 km/h (152 kt).

1.3.10 An analysis of some aircraft indicates that they may be placed in the groups as follows:

Group A

DC3
DHC6
DHC7

Group B

Avro RJ 100
DC6
DC7
Fokker F27
Fokker F28
HS146
HS748
IL76

Group C

A300, A310, A320, A330
B707-320
B727
B737
B747-SP
B757
B767
DC8 (all versions except 61 and 63)
DC9
MD80
MD90
DC10-10
L1011-200

Group D

A340
B747
B777
DC8 (61 and 63)
DC10-30/40
MD-11
IL62
IL86
IL96
L1011-500
TU154

1.3.11 The number of exit taxiways will depend on the types of aircraft and number of each type that operate during the peak period. For example, at a very large aerodrome, most aircraft will likely be in groups C or D. If so, only two exits may be required. On the other hand, an aerodrome having a balanced mixture of all four groups of aircraft may require four exits.

1.3.12 Using the Three Segment Method, the total distance required from the landing threshold to the point of turn-off from the runway centre line can be determined according to the method illustrated in Figure 1-15.

The total distance S is the sum of three distinct segments which are computed separately.

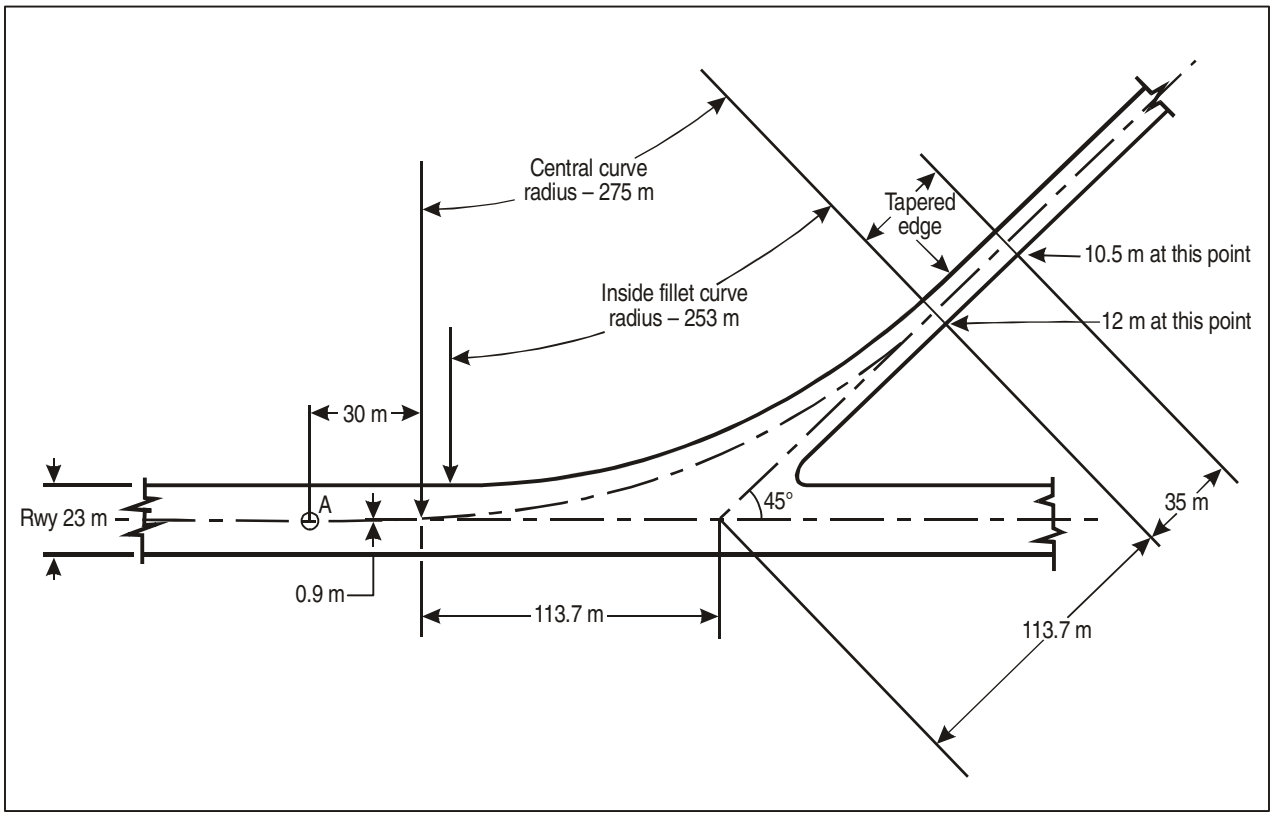

Figure 1-13. Design for rapid exit taxiways (code number 1 or 2)

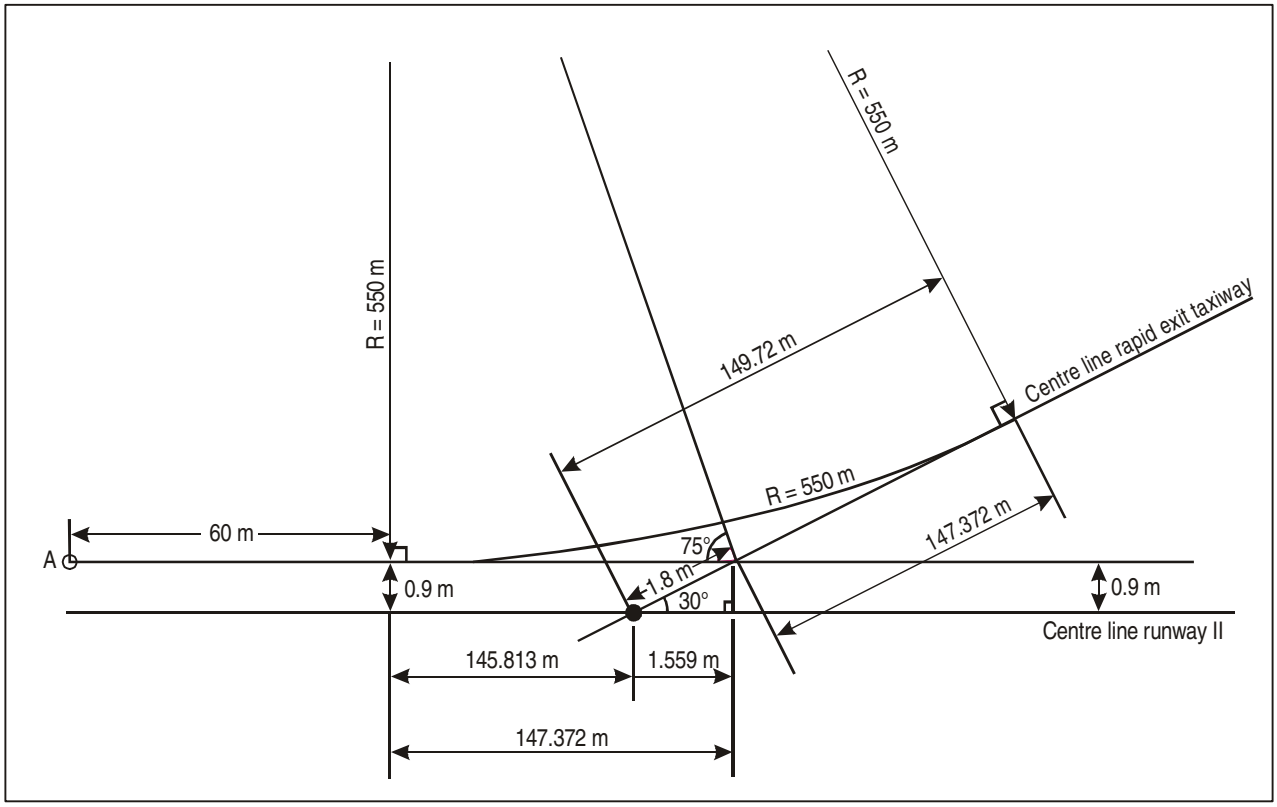

Figure 1-14. Design for rapid exit taxiways (code number 3 or 4)

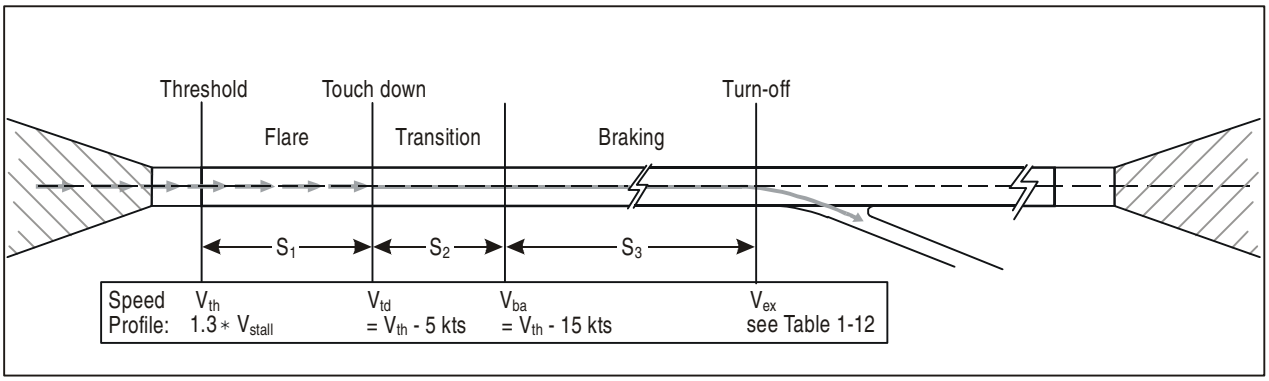

Figure 1-15. Three segment method

Segment 1: Distance required from landing threshold to maingear touchdown (S_1).

Segment 2: Distance required for transition from maingear touchdown to establish stabilized braking configuration (S_2).

Segment 3: Distance required for deceleration in a normal braking mode to a nominal turnoff speed (S_3).

Speed profile**:**

V_{th} Threshold speed based on 1.3 times the stall speed of assumed landing mass equal to 85 per cent of maximum landing mass. Speed is corrected for elevation and airport reference temperature.

V_{td} Assumed as V_{th} – 5 kts (conservative). Speed decay considered representative for most types of aircraft.

V_{ba} Assumed brake application speed.

V_{th} – 15 kts (wheel brakes and/or reverse thrust application).

V_{ex} Nominal turn-off speed:
Code number 3 or 4: 30 kts
Code number 1 or 2: 15 kts

for standard rapid exit taxiways according to Figures 1-13 and 1-14.

For other types of exit taxiways see Table 1-11 and Figure 1-16 for turn-off speed.

Distances [in m]:

S_1 Empirically derived firm distance to mean touchdown point, corrected for downhill slope and tailwind component where applicable.

Aircraft category C and D:	S_1 = 450 m
Correction for slope:	+ 50 m / - 0.25%
Correction for tailwind:	+ 50 m / + 5 kts

Aircraft category A and B:	S_1 = 250 m
Correction for slope:	+ 30 m / - 0.25%
Correction for tailwind:	+ 30 m / + 5 kts

S_2 The transition distance is calculated for an assumed transition time (empirical) Δt = 10 seconds at an average ground speed of:

$$S_2 = 10 \times V_{av} \quad [V_{av} \text{ in m/s}] \text{ , or}$$

$$S_2 = 5 \times (V_{th} - 10) \quad [V_{th} \text{ in kts}]$$

S_3 The braking distance is determined based on an assumed deceleration rate 'a' according to the following equation:

$$S_3 = \frac{V_{ba}^2 - V_{ex}^2}{2a} \; [V \text{ in m/s}, a \text{ in m/s}^2] \text{ , or}$$

$$S_3 = \frac{(V_{th} - 15)^2 - V_{ex}^2}{8a} \; [V \text{ in kts}, a \text{ in m/s}^2]$$

A deceleration rate of a = 1.5 m/s^2 is considered a realistic operational value for braking on wet runway surfaces.

1.3.13 The final selection of the most practical rapid exit taxiway location(s) must be considered in the overall planning requirements, taking into account other factors such as:

— location of the terminal/apron area

— location of other runways and their exits

— optimization of traffic flow within the taxiway system with respect to traffic control procedures

— avoidance of unnecessary taxi detours, etc.

Furthermore, there may be a need to provide additional exit taxiways — especially at long runways — after the main rapid exit(s) depending upon local conditions and requirements. These additional taxiways may or may not be rapid exit taxiways. Intervals of approximately 450 m are recommended up to within 600 m of the end of the runway.

1.3.14 Some aerodromes have heavy activity of aircraft in code number 1 or 2. When possible, it may be desirable to accommodate these aircraft on an exclusive runway with a rapid exit taxiway. At those aerodromes where these aircraft use the same runway as commercial air transport operations, it may be advisable to include a rapid exit taxiway to expedite ground movement of the small aircraft. In either case, it is recommended that this exit taxiway be located at 450 m to 600 m from the threshold.

Chapter 3

APRONS

An apron is a defined area intended to accommodate aircraft for purposes of loading and unloading passengers, mail or cargo, fuelling and parking or maintenance. The apron is generally paved but may occasionally be unpaved; for example, in some instances, a turf parking apron may be adequate for small aircraft.

3.1 TYPES OF APRONS

Passenger terminal apron

3.1.1 The passenger terminal apron is an area designed for aircraft manoeuvring and parking that is adjacent or readily accessible to passenger terminal facilities. This area is where passengers board the aircraft from the passenger terminal. In addition to facilitating passenger movement, the passenger terminal apron is used for aircraft fuelling and maintenance as well as loading and unloading cargo, mail and baggage. Individual aircraft parking positions on the passenger terminal apron are referred to as aircraft stands.

Cargo terminal apron

3.1.2 Aircraft that carry only freight and mail may be provided a separate cargo terminal apron adjacent to a cargo terminal building. The separation of cargo and passenger aircraft is desirable because of the different types of facilities each requires both on the apron and at the terminal.

Remote parking apron

3.1.3 In addition to the terminal apron, airports may require a separate parking apron where aircraft can park for extended periods. These aprons can be used during crew layovers or for light periodic servicing and maintenance of temporarily grounded aircraft. While parking aprons are removed from the terminal aprons, they should be located as close to them as is practical to minimize the time for passenger loading/unloading as well as from a security point of view.

Service and hangar aprons

3.1.4 A service apron is an uncovered area adjacent to an aircraft hangar on which aircraft maintenance can be performed, while a hangar apron is an area on which aircraft move into and out of a storage hangar.

General aviation aprons

3.1.5 General aviation aircraft, used for business or personal flying, require several categories of aprons to support different general aviation activities.

Itinerant apron

3.1.5.1 Itinerant (transient) general aviation aircraft use the itinerant apron as temporary aircraft parking facilities and to access fuelling, servicing and ground transportation. At aerodromes servicing only general aviation aircraft, the itinerant apron is usually adjacent to, or an integral part of, a fixed-based operator's area. The terminal apron will generally also set aside some area for itinerant general aviation aircraft.

Base aircraft aprons or tiedowns

3.1.5.2 General aviation aircraft based at an aerodrome require either hangar storage or a tiedown space in the open. Hangared aircraft also need an apron in front of the building for manoeuvring. Open areas used for base

aircraft tiedown may be paved, unpaved or turf, depending on the size of aircraft and local weather and soil conditions. It is desirable that they be in a separate location from the itinerant aircraft aprons.

Other ground servicing aprons

3.1.5.3 Areas for servicing, fuelling or loading and unloading should also be provided as needed.

3.2 DESIGN REQUIREMENTS

3.2.1 The design of any of the various apron types requires the evaluation of many interrelated and often contradictory characteristics. Despite the distinct purposes of the different apron types, there are many general design characteristics relating to safety, efficiency, geometry, flexibility and engineering that are common to all types. The following paragraphs give a brief description of these general design requirements.

Safety

3.2.2 Apron design should take into account safety procedures for aircraft manoeuvring on the apron. Safety in this context implies that aircraft maintain specified clearances and follow the established procedures to enter, move within and depart from apron areas. Services provided to aircraft parked on the apron should incorporate safety procedures, especially regarding aircraft fuelling. Pavements should slope away from terminal buildings and other structures to prevent the spread of fuel fires on the apron. Water outlets should be located at each stand position for routine hosing of the apron surface. Aircraft security should also be considered in locating the apron area where the aircraft can be protected from unauthorized personnel. This is accomplished by physically separating public access areas from the apron areas.

Efficiency

3.2.3 Apron design should contribute to a high degree of efficiency for aircraft movements and dispensing apron services. Freedom of movement, minimum taxi distances and a minimum of delay for aircraft initiating movements on the apron are all measures of efficiency for any of the apron types. If the ultimate aircraft stand arrangement can be determined during the initial planning phase of the aerodrome, utilities and services should be installed in fixed installations. Fuel lines and hydrants, compressed air hookups and electrical power systems must be carefully preplanned because these systems are often placed under the apron pavement. The high initial cost of these systems will be offset by the increased efficiency of the stand, which allows greater utilization of the apron. Achieving these measures of efficiency will ensure the maximum economic value of the apron.

Geometry

3.2.4 The planning and design of any apron type are dependent upon a number of geometric considerations. For example, the length and width of a land parcel available for apron development may preclude the choice of certain apron layout concepts. For a new aerodrome it may be possible to develop the most efficient arrangement, based upon the nature of the demand, and then to set aside an area of land ideally suited to the plan. However, expansion or addition of aprons at existing aerodromes will usually be less than ideal due to the limitations imposed by the shape and size of available parcels. The overall area needed per aircraft stand includes the area required for aircraft stand taxilanes as well as apron taxiways used in common with other aircraft stands. Therefore, the overall area needed for apron development is a function not only of aircraft size, clearances and parking method, but also of the geometric arrangement of aircraft stand taxilanes, other taxiways, blast fences, areas used for the stationing of service vehicles and roads for the movement of ground vehicles.

Flexibility

3.2.5 Planning for aprons should include an evaluation of the following flexibility characteristics.

Range of aircraft sizes

3.2.5.1 The number and size of aircraft stands should be matched to the number and size of aircraft types expected to use the apron. A compromise must be developed between the extremes of:

a) using one size of aircraft stand large enough for the largest aircraft type; and

b) using as many different sized stands as there are aircraft types.

The first method is a highly inefficient use of area, while the second provides a low level of operating flexibility. For passenger terminal aprons, a compromise solution that achieves adequate flexibility is to group the aircraft into two to four size classes and provide stands for a mix of these general sizes in proportion to the demand forecast. A greater number of general aviation parking space sizes can be used because the space may be leased and occupied by a single aircraft of known dimensions.

Expansion capability

3.2.5.2 Another key element of a flexible apron system is allowance for expansion to meet future needs. To avoid undue restriction of the growth potential of a particular apron area, the apron should be designed in modular stages so that successive stages become integral additions to the existing apron with a minimum of disruption to ongoing activities.

Common design characteristics

3.2.6 Many technical design requirements for the construction of apron surfaces are common to all apron types. Several of these factors are described in the following paragraphs.

Pavement

3.2.6.1 The choice of pavement surface is determined by evaluating aircraft mass, load distribution, soil conditions and the relative cost of alternative materials. Reinforced concrete is routinely used at aerodromes serving the largest commercial aircraft where greater strength and durability are needed. As a minimum, most aerodromes require an asphalt (tarmac) surface to satisfy strength, drainage and stabilization criteria, though turf and cement-stabilized sand aprons have been satisfactorily used in some locations. Reinforced concrete is usually more expensive to install than asphalt but is less expensive to maintain and usually lasts longer. In addition, concrete is relatively unaffected by spilled jet fuel, whereas asphalt surfaces are damaged if fuel remains on the surface for even short periods of time. This problem can be partially overcome by coating the asphalt with special sealants and by frequently washing off the pavement.

Pavement slope

3.2.6.2 Slopes on an apron should be sufficient to prevent accumulation of water on the surface of the apron but should be kept as level as drainage requirements permit. Efficient storm drainage of large, paved apron areas is normally achieved by providing a steep pavement slope and numerous area drains. On aprons, however, too great a slope will create manoeuvrability problems for aircraft and service vehicles operating on the apron. Additionally, fuelling of aircraft requires nearly a level surface to achieve the proper fuel mass balance in the assorted aircraft storage tanks. The design of slopes and drains should direct spilled fuel away from building and apron service areas. In order to accommodate the needs for drainage, manoeuvrability and fuelling, apron slopes should be 0.5 to 1.0 per cent in the aircraft stand areas and no more than 1.5 per cent in the other apron areas.

Jet blast and propeller wash

3.2.6.3 The effects of extreme heat and air velocities from jet and propeller engines must be considered when planning apron areas and adjacent service roads and buildings. For some aerodromes, it may be necessary to provide greater aircraft-to-aircraft separations or erect blast fences between parking spaces to counteract these effects. Appendix 2 gives greater detail on this design consideration.

3.3 BASIC TERMINAL APRON LAYOUTS

General considerations

3.3.1 The type of terminal apron parking layout best suited to a particular aerodrome is a function of many interrelated criteria. Design of the terminal apron must, of course, be completely consistent with the choice of terminal design and vice versa. An iterative procedure for selecting the best combination of apron and terminal design should be used to compare the advantages and disadvantages of each system analysed separately. The volume of aircraft traffic using the terminal is an important factor in determining the apron layout that is most efficient in serving a particular terminal design. In addition, an aerodrome with a disproportionate percentage of international transfer (direct connection with another flight) or locally originating passengers may need a specialized terminal and apron system design to accommodate the skewed characteristic of the passenger traffic.

Passenger loading

3.3.2 The passenger loading method to be used must be taken into account when planning the apron layout. Some methods can be used with only one or two of the basic parking layouts.

3.3.2.1 Direct upper level loading is made possible by the development of the loading bridge, permitting the passenger to board the aircraft from the upper level of the terminal building. Two types of aircraft loading bridges are illustrated in Figure 3-1:

a) *The stationary loading bridge.* A short loading bridge which extends from a projection in the building. The aircraft parks nose-in alongside the projection and stops with the aircraft front door opposite the bridge. The bridge extends a very short distance to the aircraft, allowing very little variation between the height of the aircraft main deck and the terminal floor.

b) *The apron drive loading bridge.* A bridge which has one end of a telescoping gangway hinged to the terminal building and the other end supported by a steerable, powered dual-wheel. The bridge pivots towards the aircraft and lengthens until it reaches the aircraft door. The end mating with the aircraft can be raised or lowered significantly, permitting aircraft of varying deck heights to be served from the loading bridge.

3.3.2.2 There are other basic passenger loading methods used in addition to aircraft loading bridges:

a) *Movable steps.* Movable steps are pushed or driven to the aircraft and set at door level. Passengers walk in the open on the apron or are driven by bus between the terminal and the aircraft and use the steps to board the aircraft.

b) *Passenger transporters.* Passengers board a bus or specially designed passenger transporter at the terminal building and are driven to a remote aircraft stand. Passengers then may use steps to board the aircraft or board the aircraft from the same level as the aircraft floor, i.e. by elevation of the vehicle.

c) *Aircraft-contained steps.* This procedure is similar to the movable steps and can be used with any aircraft equipped with self-contained steps. After stopping, the crew releases the self-contained steps and passengers walk on the apron or are driven by bus between the aircraft and the terminal building.

Passenger terminal apron concepts

3.3.3 The design of passenger terminal aprons is directly interrelated with the passenger terminal concept. Determination of passenger terminal concepts is described in the *Airport Planning Manual* (Doc 9184), Part 1 — Master Planning. Various apron/terminal concepts are illustrated in Figure 3-2, and the characteristics of each concept from the viewpoint of the apron are briefly described below.

Simple concept

3.3.4 This concept is to be applied at low traffic volume airports. Aircraft are normally parked angled either nose-in or nose-out for self-taxi in and taxi out. Consideration should be given to providing adequate clearance between apron edge and air-side terminal frontage to reduce the adverse effects of jet engine blast. Where this is not done, jet engine blast fences should be provided. Apron expansion can be done incrementally in accordance with demands, causing little disruption to airport operation.

Linear concept

3.3.5 The linear concept may be regarded as an advanced stage of the simple concept. Aircraft can be parked in an angled or parallel parking configuration. However, the nose-in/push-out parking configuration with minimum clearance between apron edge and terminal is more common in this concept because of more efficient utilization of apron space and handling of aircraft and passengers. Nose-in parking affords relatively easy and simple manoeuvring for aircraft taxiing into gate position. Push-out operations cause little disruption of apron activities in neighbouring gate positions. However, towing tractors and skilled operators are required. At busy traffic airports, it may become necessary to provide double apron taxiways to lessen the blocking of the taxiway by push-out operations. The corridor between the apron edge and terminal frontage can be used for circulation of apron traffic, and the area around the nose of the parked aircraft can be used for ground service equipment parking slots. When apron depth is planned from the outset to cater to the longest fuselage length, the linear concept has as much flexibility and expansibility as the simple concept and almost as much as the open apron concept.

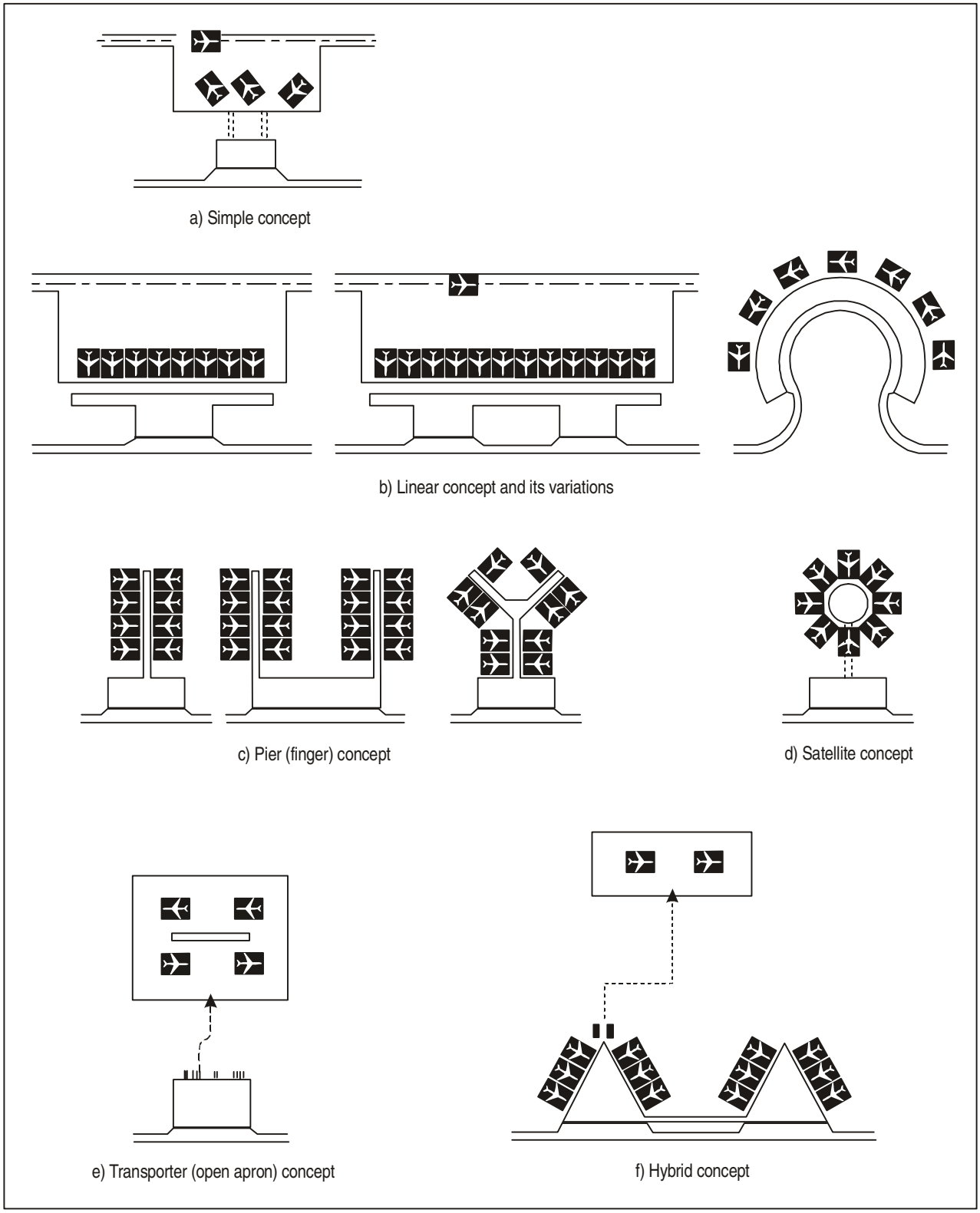

Figure 3-2. Passenger terminal apron concepts

Pier (finger) concept

3.3.6 As seen in Figure 3-2, there are several variations on this concept, according to the shape of the pier. Aircraft can be parked at gate positions on both sides of the piers, either angled, parallel or perpendicular (nose-in). Where there is only a single pier, most advantages of the linear concept would apply for air side activities with the exception that the pier concept has a limited incremental expansion capability. When there are two or more piers, care must be taken to provide proper space between them. If each pier serves a large number of gates, it may be necessary to provide double taxiways between piers to avoid conflicts between aircraft entering and leaving the gate positions. It is important to provide sufficient space between two or more piers to cater to future larger aircraft.

Satellite concept

3.3.7 The satellite concept consists of a satellite unit, surrounded by aircraft gate positions, separated from the terminal. The passenger access to a satellite from the terminal is normally via an underground or elevated corridor to best utilize the apron space, but it could also be on the surface. Depending on the shape of the satellite, the aircraft are parked in radial, parallel or some other configuration around the satellite. When aircraft are parked radially, push-back operation is easy but requires larger apron space. If a wedge-shaped aircraft parking configuration is adopted, it not only requires unfavourable sharp turns taxiing to some of the gate positions but also creates traffic congestion of ground service equipment around the satellite. A disadvantage of this concept is the difficulty of incremental expansion which means that an entire new unit would need to be constructed when additional gate positions are required.

Transporter (open) apron concept

3.3.8 This concept may be referred to as an open or remote apron or transporter concept. As aprons may be ideally located for aircraft, i.e. close to the runway and remote from other structures, this concept would provide advantages for aircraft handling, such as shorter overall taxiing distance, simple self-manoeuvring, ample flexibility and expansibility of aprons. However, as it requires transporting passengers, baggage and cargo for relatively longer distances by transporters (mobile lounges/buses) and carts to and from the terminal, it can create traffic congestion problems on the air side.

Hybrid concept

3.3.9 The hybrid concept means the combining of more than one of the above-mentioned concepts. It is fairly common to combine the transporter concept with one of the other concepts to cater to peak traffic. Aircraft stands located at remote areas from the terminal are often referred to as remote aprons or remote stands.

3.4 SIZE OF APRONS

General

3.4.1 The amount of area required for a particular apron layout depends upon the following factors:

a) the size and manoeuvrability characteristics of the aircraft using the apron;

b) the volume of traffic using the apron;

c) clearance requirements;

d) type of ingress and egress to the aircraft stand;

e) basic terminal layout or other airport use (see 3.3);

f) aircraft ground activity requirements; and

g) taxiways and service roads.

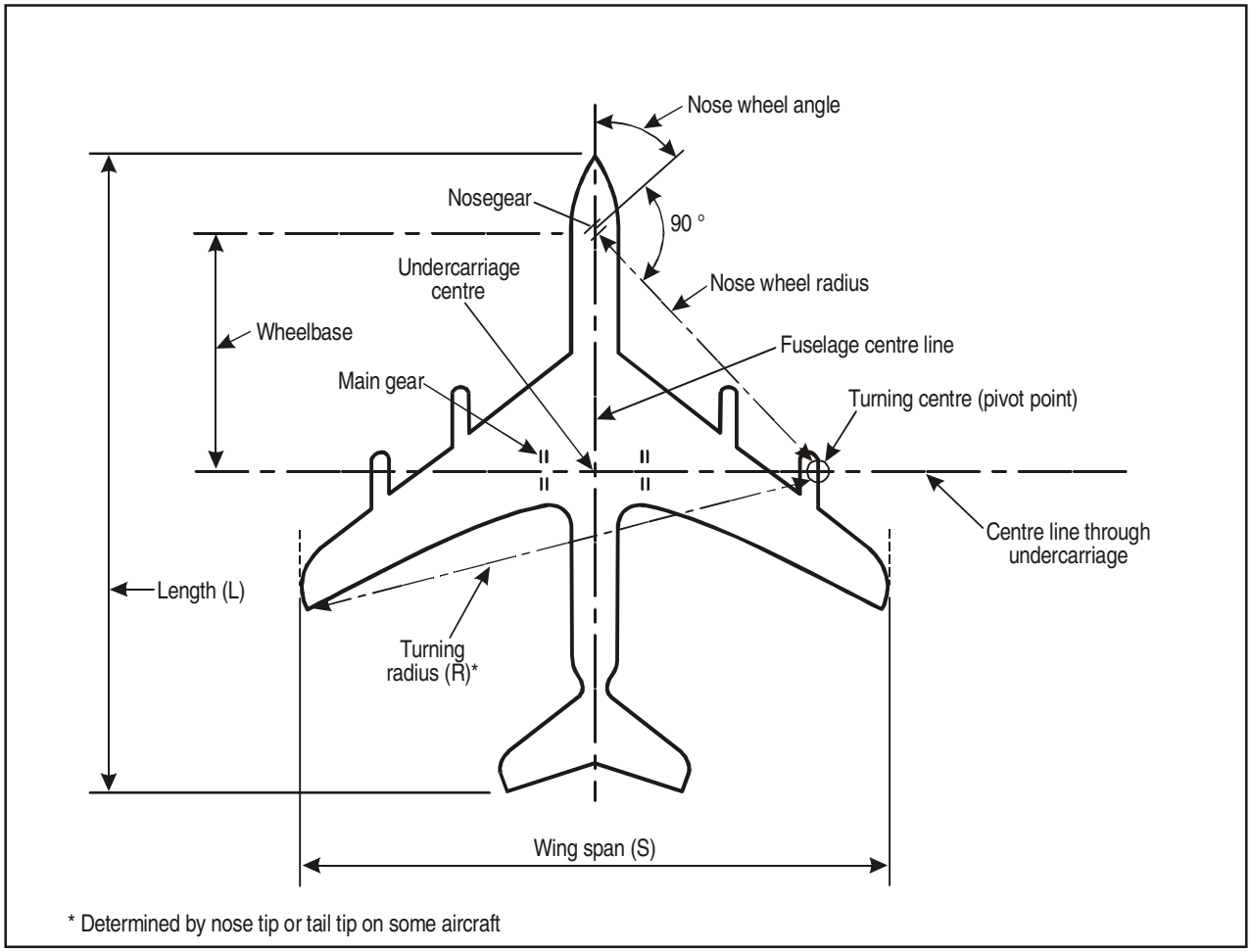

Figure 3-3. Dimensions for sizing aircraft stand spacing